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Shallow Gas Deposit and Its Environmental Implications in the Southeastern Part of Korea, the East Sea (Japan Sea)

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Abstract - Physical and acoustic properties and electrical resistivity as well as sediment textures on gassy mud deposits in the southeastern shelf of Korea were studied to reveal the systematics of vertical variations of the parameters. Other field surveys such as high resolution subbottom profiling and sidescan sonar have been performed to investigate the depth and distribution of the acoustic turbid layer that generated by masking effect of gas bubbles. The horizontal distribution of the gas charged zone was determined accurately though the thickness was still unclear. The compressional wave velocity decreases abruptly in the gassy layer due to scattering effect of free gas bubble. Among other physical properties, only electrical resistivity coincides the patterns of velocity.

I. Introduction

Free gas bubbles, that are compose of mostly methane, in shallow marine environment arise characteristic phenomena such as acoustic blanking, delaying of seismic wave propagation and increasing attenuation. They also induce blow out features like pockmark and plume. These methane bubbles are generated by biogeochemical processes in organic-rich marine sediments that are common in coastal and shallow seas. The shallow gas also affects the global climatic change by its greenhouse effect. Global warming potential of methane is 3.7 times that of carbon dioxide. Thus the shallow marine methane also contributes global warming [1].

The acoustic turbid zone (AT) in high resolution subbottom profiling, arises by scattering of acoustic signal, is very common in organic-rich muddy sediment of coastal waters. Fig. 1 shows the shallow gas distribution in the world [2]. The actual locations should be much greater because the map was based on very limited data particularly concentrated on northern hemisphere. Other AT zones that reported recently in Korea, investigated by high resolution subbottom profiling, are compiled in Fig. 2 [3, 4].

II. Study Area

Inner continental shelf of Korea is dominated by Holocene mud. The belt-shaped Holocene mud so-called mud belt extends from west to southeast. The study area lies in the southeast extension of the mud belt of Korea (Fig. 3). The belt develops from the western part (the Yellow Sea) to the study area (the East Sea and/or Japan Sea). The water depth of the offshore boundary of the belt lies between 70 to 80 meters. The boundary, however, extends to a greater depth (100-120m) near the study area. The width of the belt decreases from the east of Busan and finally disappears at the south of Pohang. The average thickness of the mud is 30-40m [5].

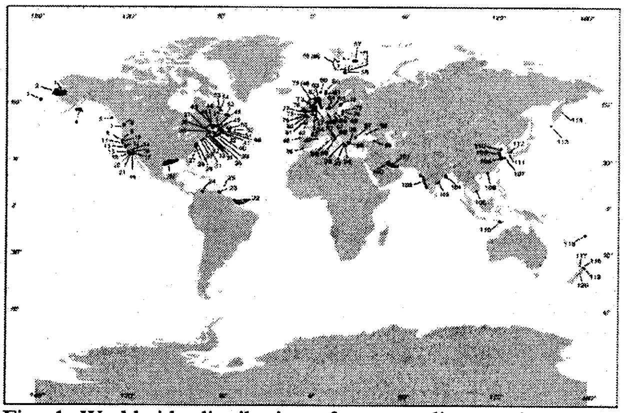


Fig. 1. Worldwide distribution of gassy sediments. Most sites were located with seismoacoustic techniques.

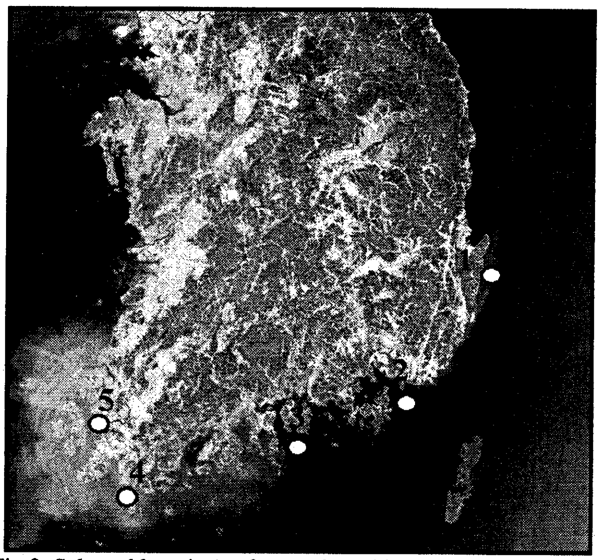
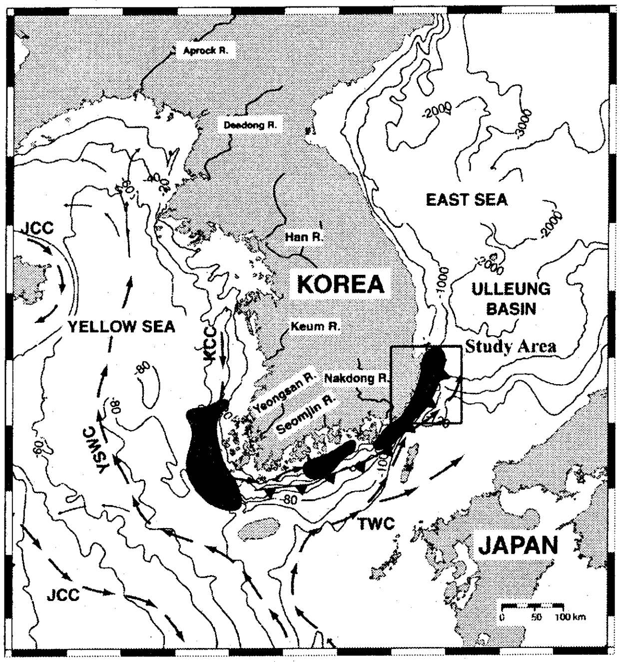


Fig.2. Selected locations of acoustic turbid (AT) zone of Korea.

A handful of reports that indicating the extensive distribution of acoustic turbid layer that is related to shallow gas are available in the area. This area is also famous for frequent coastal upwelling [6, 7](Fig. 4).



TWC : Tsushima Warm Current
JCC : Jiangsu Coastal Current
YSWC : Yellow Sea Warm Current
KCC : Korean Coastal Current

Fig.3. Map showing surface-current directions, mud belts and bathymetry around the Korean seas. Contours in meters.

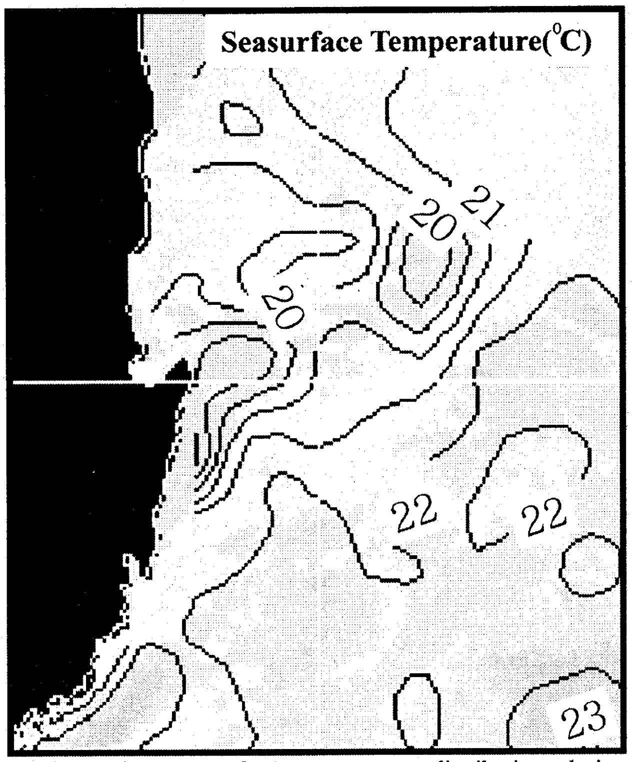


Fig.4. Typical seasurface temperature distribution during summer upwelling in the study area. Note the low temperature contour (<20°C) in the southeast coast.

III. Methods and Materials

High resolution subbottom profiling (Chirp Acoustic Profiler) and sidescan sonar survey have been carried out for past three years. R/V Tamyang of Pukyong National University was employed for the suvery. We found a lot of gas seepage, pock marks and other typical features of shallow gas in the study area. Nine piston core samples were collected from the representative three track lines (Fig. 5).

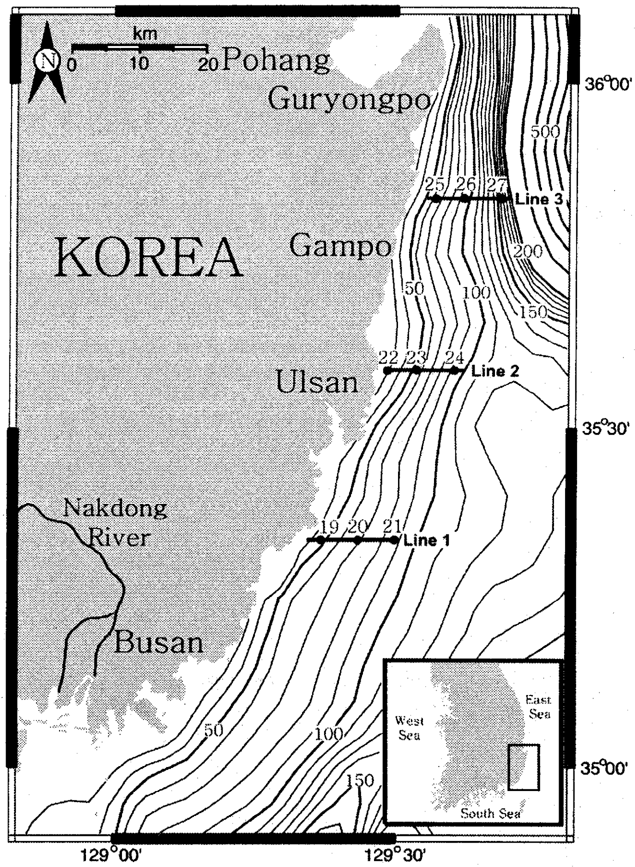


Fig. 5. Bathymetry of the study area. Dots with numbers indicate the coring positions and solid lines indicate chirp sonar track lines. Contours in meters.

The core lengths are up to 3 to 4 meters. Among them one core (Site 25) hit the gas layer. The cores were cut into two halves using a core splitter. On each half, acoustic and physical properties as well as textural parameters were measured for similar interval. (10-30 cm)

Compressional wave velocity, density, porosity, electrical resistivity, vane shear strength and sediment textural properties have been measured along the cores. Velocity was determined using pulse transmission technique. The resonance frequency (1 MHz) was maintained to satisfy the wavelength of the transmitted pulse should larger than the largest grain size of the specimen [8]. Automated velocity measurement system was applied to obtain accurate data (Fig. 6). This system is quite useful particularly for mud samples [9]. Hellium pycnometer was employed for density and porosity determination. Motorized shear vane was used to measure shear strength for mud samples. Four-electrode method that minimizes electrochemical polarization was used for resistiviy measurement [10].

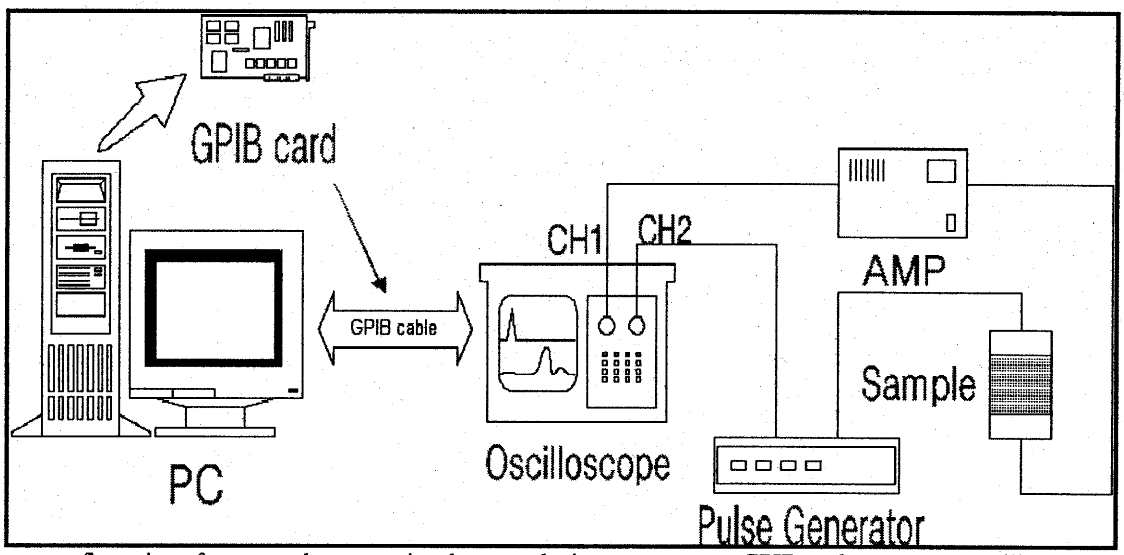


Fig. 6. System configuration of automated compressional wave velocity measurement. GPIB card connects an oscilloscope to a computer. Cursors are used to pick up the first arrival of each signal.

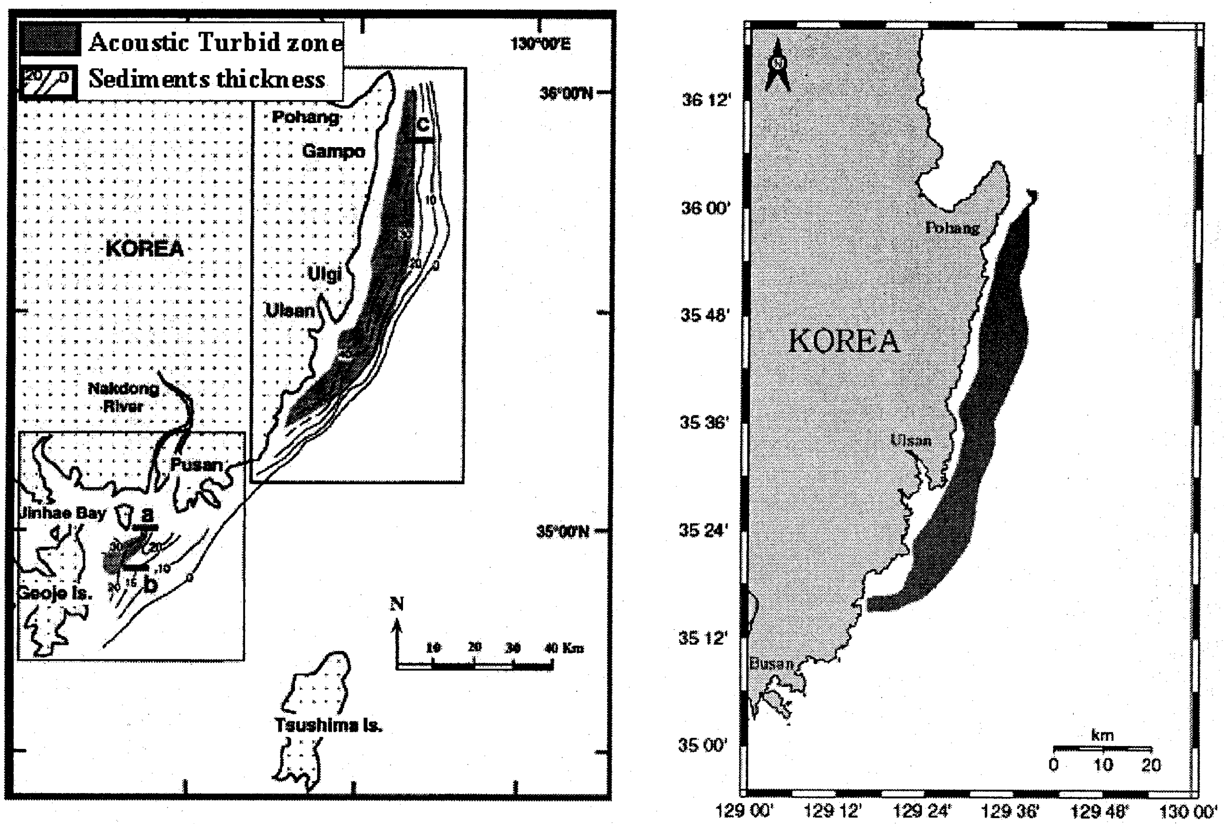


Fig. 7. Horizontal distribution of gas charged sediment in the study area. Shaded regions indicate the occurrence of acoustic turbid zone. Compared to previous study (left [14]), the location of gas zone shift closer to land (right).

Sediment texture was analyzed following the direction of standard sedimentation method [11, 12]. X-radiograph study has been done for all core to observe the effect of escaping free gas. Quantitative analysis of gas was conducted using gas chromatography. The sediment cores were frozen immediately after recovered to prevent gas leaking.

IV. Results and Discussion

Thanks to the continuous efforts of high resolution subbottom profiling the lateral extent of shallow gas zone was mapped. Compared to previous study, the location of gas zone shift closer to land (Fig. 7). However, the depth of turbid zone is still unclear due to its high frequency profiling system. Seasonal variation is also not investigated.

The velocity decreases dramatically at the gas horizon. It drops abruptly from 1500 m/s to slower than 1300 m/s with the occurrence of gas layers. Other physical properties such as bulk density, porosity and vane shear strength change little. Only electrical resistivity shows similar trends as velocity. This may indicate that the existing gas bubble affects sediment microstructure that results in both velocity and resistivity [13]. No downcore variation of the physical and acoustic properties was observed for the gas-free cores. Degassing cracks that have elongated geometry attributed from escaping gas were observed commonly at the gas zone (Fig. 8). Estimated total volume of gas charged deposit in the study area is about 117.4 km^3 and average gas concentration is approximately 25 ml/l.

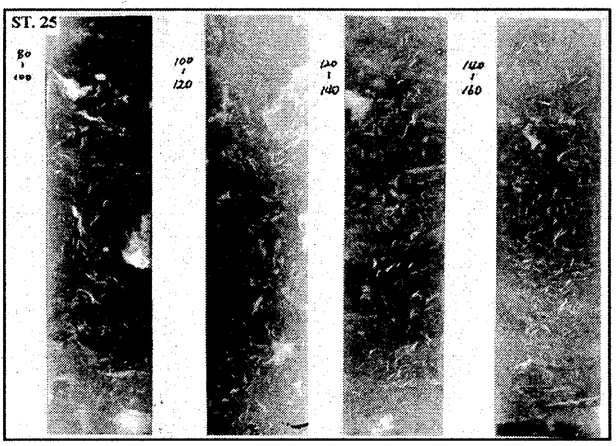


Fig. 8. X-ray radiograph images of gas charged sediment cores. Note the shape of degassing cracks.

V. Summary

The shallow gas zone distributes in the southeastern shelf of Korea widely. Typical features such as pockmark, plume and seepage are commonly observed. This area also coincides well with coastal upwelling zone. The compressional wave velocity decreases dramatically in the gas charged sediment but no other physical properties change except electrical resistivity indicating the effect of gas bubble on velocity and resistivity. The amount of gas lies between 1 to 4 percent. It seems that source of gas is related with frequent upwelling that supply organic matters. Further study is needed to understand the origin of gas either biogenic or thermogenic.

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